A Current Assessment of the Nature of $PM_{2.5}$ in Steubenville, Ohio, Using SCAMP Monitoring Data

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Why Steubenville?

- Most polluted of the Harvard Six Cities
  - Mean $PM_{2.5}$ Concentration = 29.6 µg/m^3, 1979-1985
  - Extensive $PM_{2.5}$ data record
- Major changes have occurred
  - Steubenville-Weirton MSA lost 4,200 manufacturing jobs in 1990s (decline of steel industry)
  - Population decreased by 7.4% in 1990s
- Likely a nonattainment area under $PM_{2.5}$ NAAQS

The Steubenville Comprehensive Air Monitoring Program (SCAMP)

- Two-year comprehensive program for monitoring $PM_{2.5}$ and co-pollutants
- Steubenville, Ohio, and surrounding region
- May 2000 – May 2002
- Two major study components:
  - Indoor/Personal
    - Personal sampling of children and elderly volunteers
    - Indoor sampling in participants' homes
  - Outdoor
    - Participants' homes
    - Central site in Steubenville
    - Four remote sites located at cardinal compass points around Steubenville

SCAMP Outdoor Ambient Goals

- Compare urban $PM_{2.5}$ concentration / composition with remote $PM_{2.5}$ concentration / composition (determined using FRM)
- Study associations among $PM_{2.5}$, co-pollutants, and weather conditions
- Provide a comprehensive database for use in epidemiological and transport studies and in compliance program development

Steubenville Site

- $PM_{2.5}$ FRM
  - Mass (1/1 $days^{-1}$)
  - Ions (1/4)
  - Elements in WS Fraction (1/4)
- $PM_{2.5}$ Speciation Sampler
  - EC, OC (1/4)
  - Elements in Acid-Digestible Fraction (1/4)
- $PM_{2.5}$ TEOM
  - Mass (continuous)
- PM_{10} FRM
  - Mass (1/1)
  - Ions (1/4)
  - Elements in WS Fraction (1/4)

- FRM or FEM Gas Analyzers
  - SO_2, CO, NO_x, O_3 (continuous)
- 10-m Meteorological Tower
  - Weather Conditions (continuous)
- Burkard Volumetric Spore Trap
  - Pollen and Mold Spores (1/1)

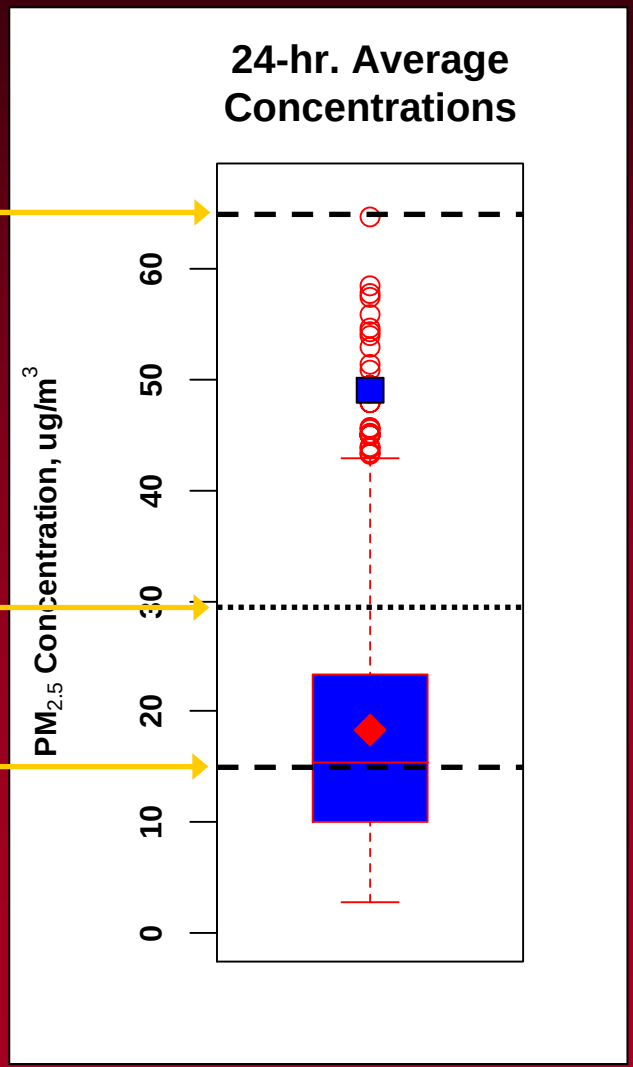
Steubenville $PM_{2.5}$ Concentration / Composition

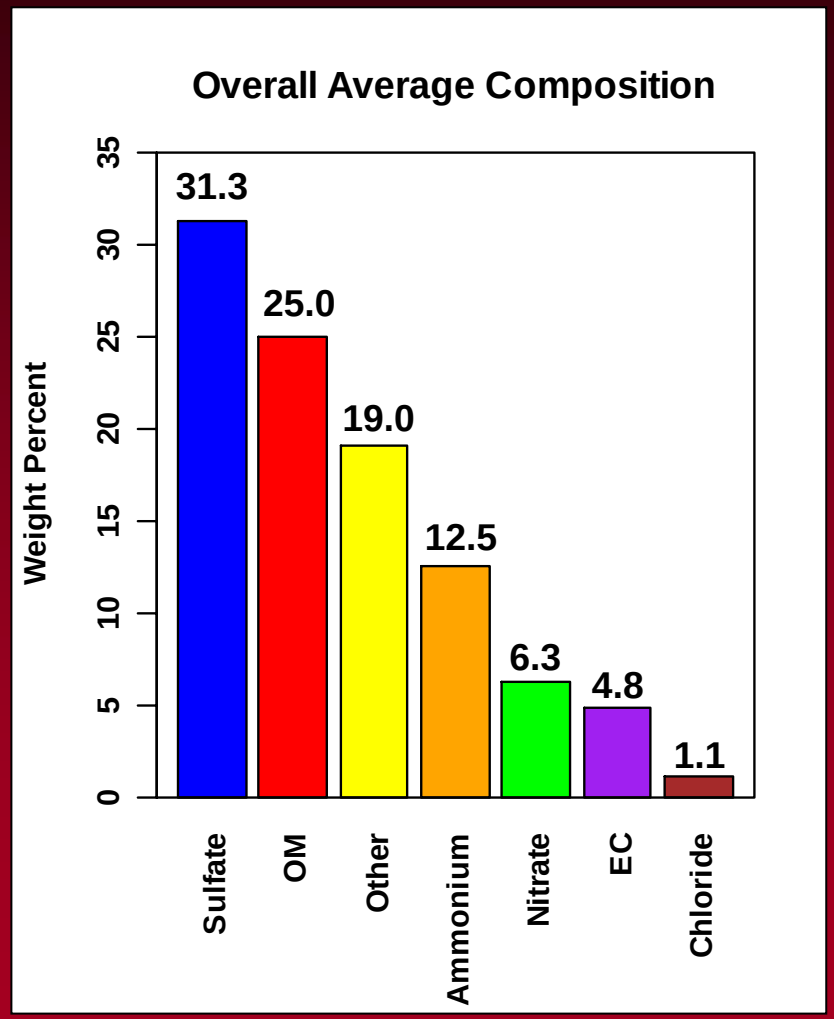
May 2000 – May 2002

24-hr. NAAQS

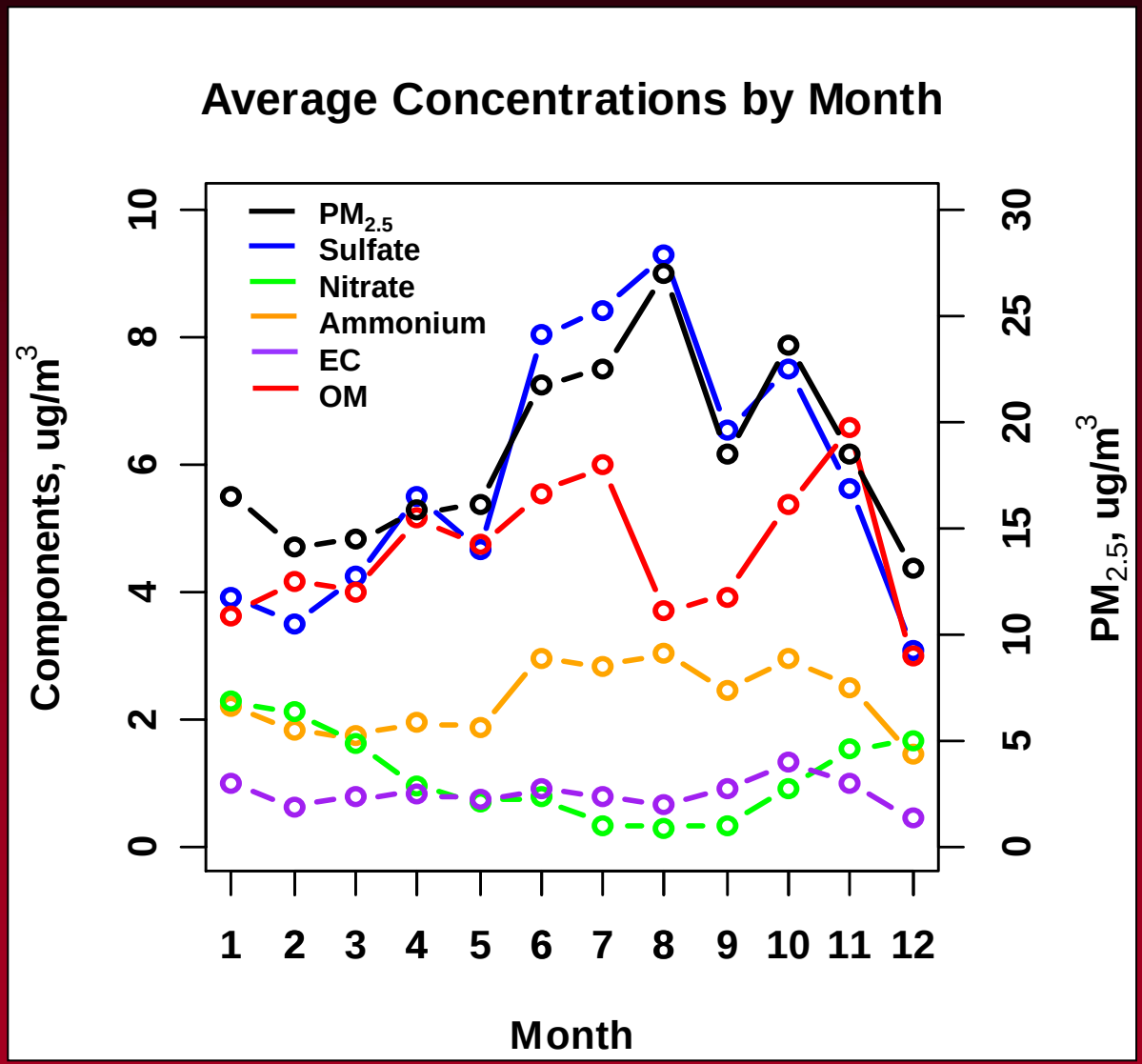
Six Cities Study Mean

Annual NAAQS

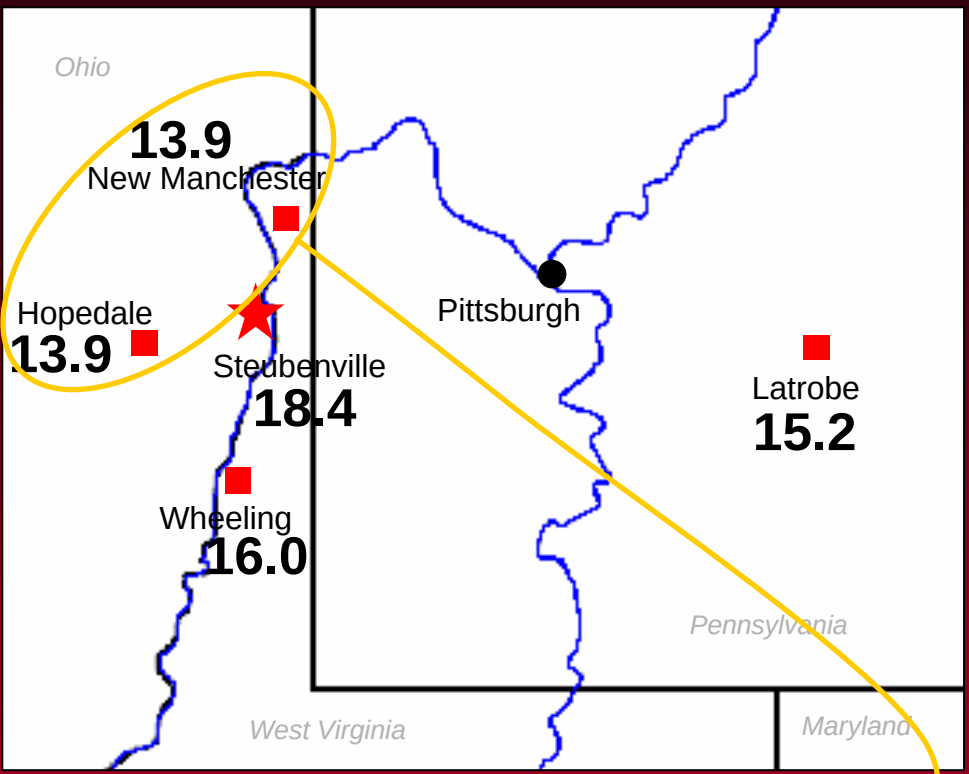




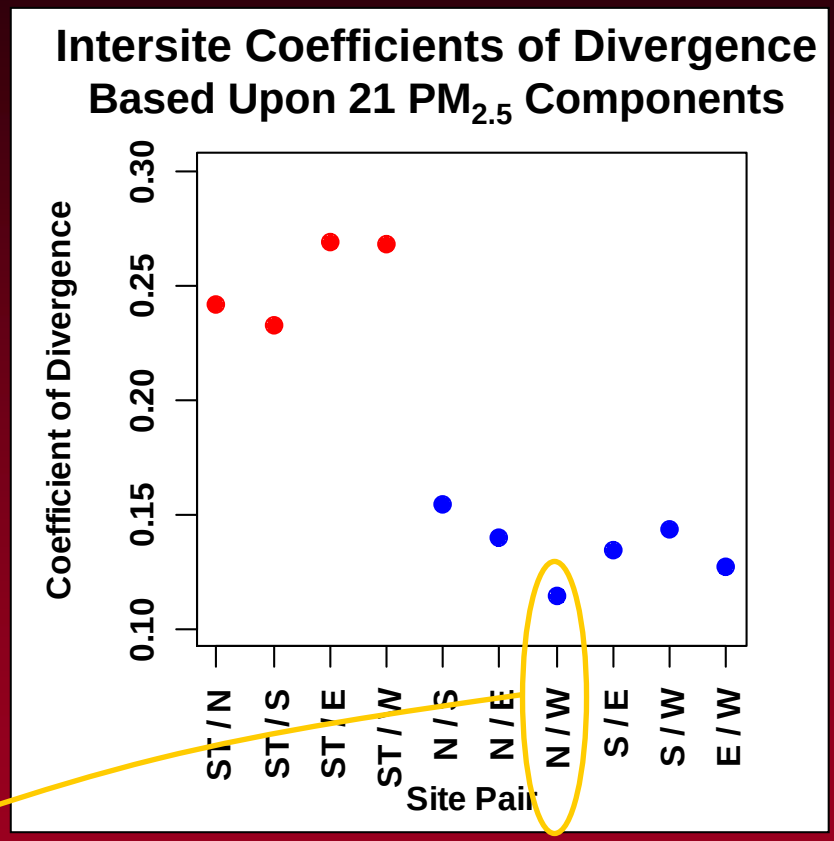
Seasonal Variability



Spatial Variability



Less Similar

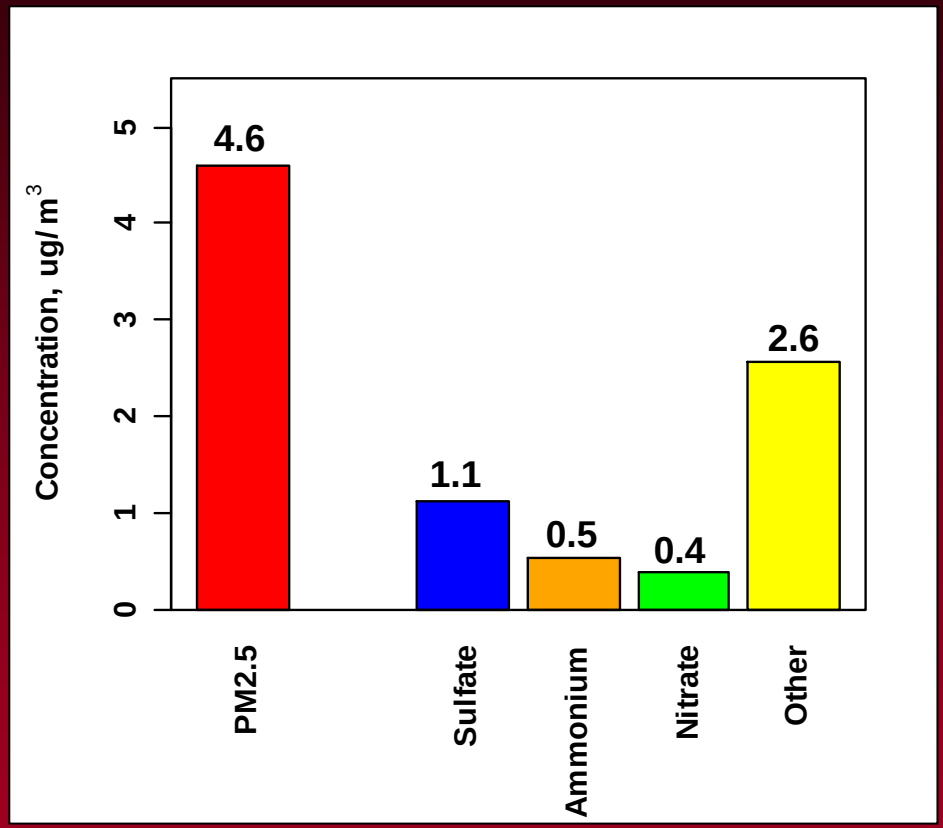


"Background" Sites

$$CD_{jk} = \sqrt{\frac{1}{p}\sum_{i=1}^{p}\left(\frac{x_{ij} - x_{ik}}{x_{ij} + x_{ik}}\right)^2}$$

Local Source Contributions

$PM_{2.5}$ and Major Components



84 71 68 82

% ST > BG

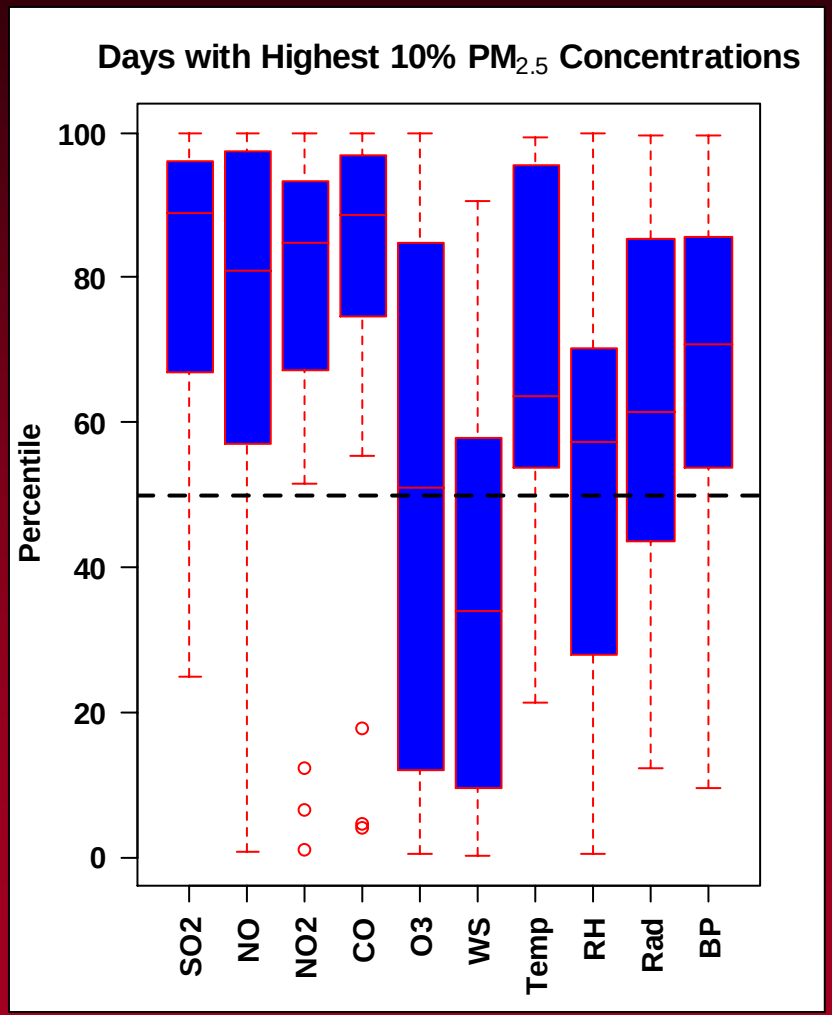
Local Source Contributions

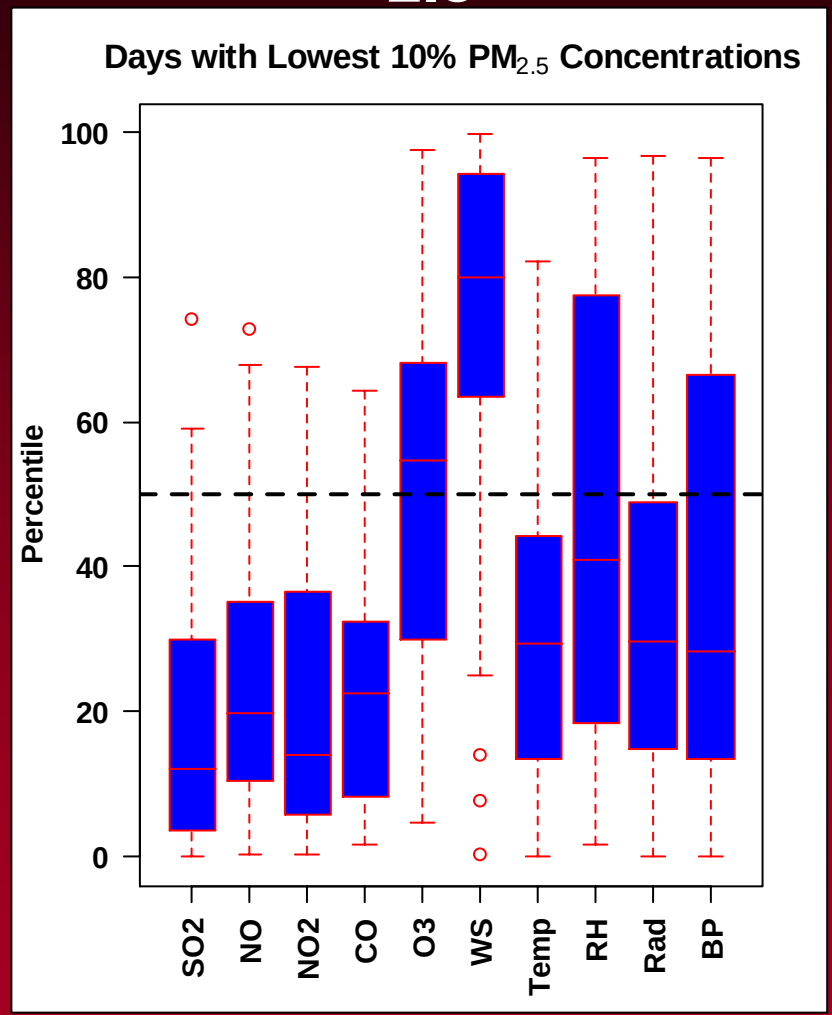
Elements in the Water-Soluble Fraction

	% ST > BG	Loc. (ng/m³)	Loc. (% of BG)
Al	71	4.8	49
As	73	0.66	43
Ba	79	0.7	65
Cd	71	0.10	31
Ca	73	28	46
Co	43	-0.004	-10
Cu	59	0.7	31
Fe	71	11.8	106
Pb	69	3.1	78

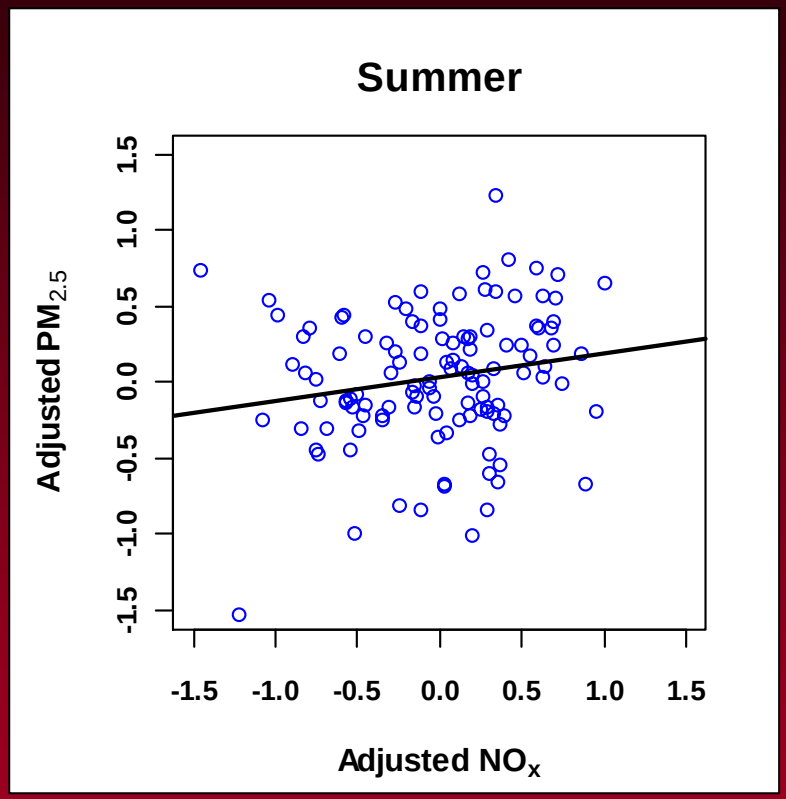
	% ST > BG	Loc. (ng/m³)	Loc. (% of BG)
Mg	79	18	145
Mn	83	4.5	154
Ni	47	0.1	11
K	59	16	21
Se	54	-0.44	-9
Na	73	19	32
Sn	38	-0.017	-9
V	63	0.44	66
Zn	75	25.5	140

Gas and Weather Percentiles On Highest / Lowest $PM_{2.5}$ Days

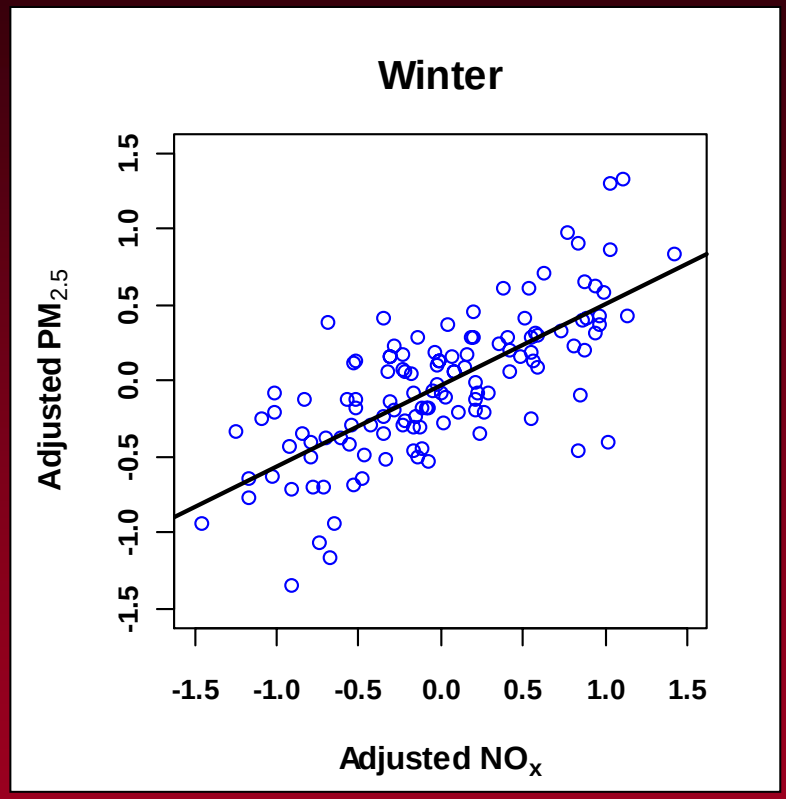




Seasonally Dependent Correlations

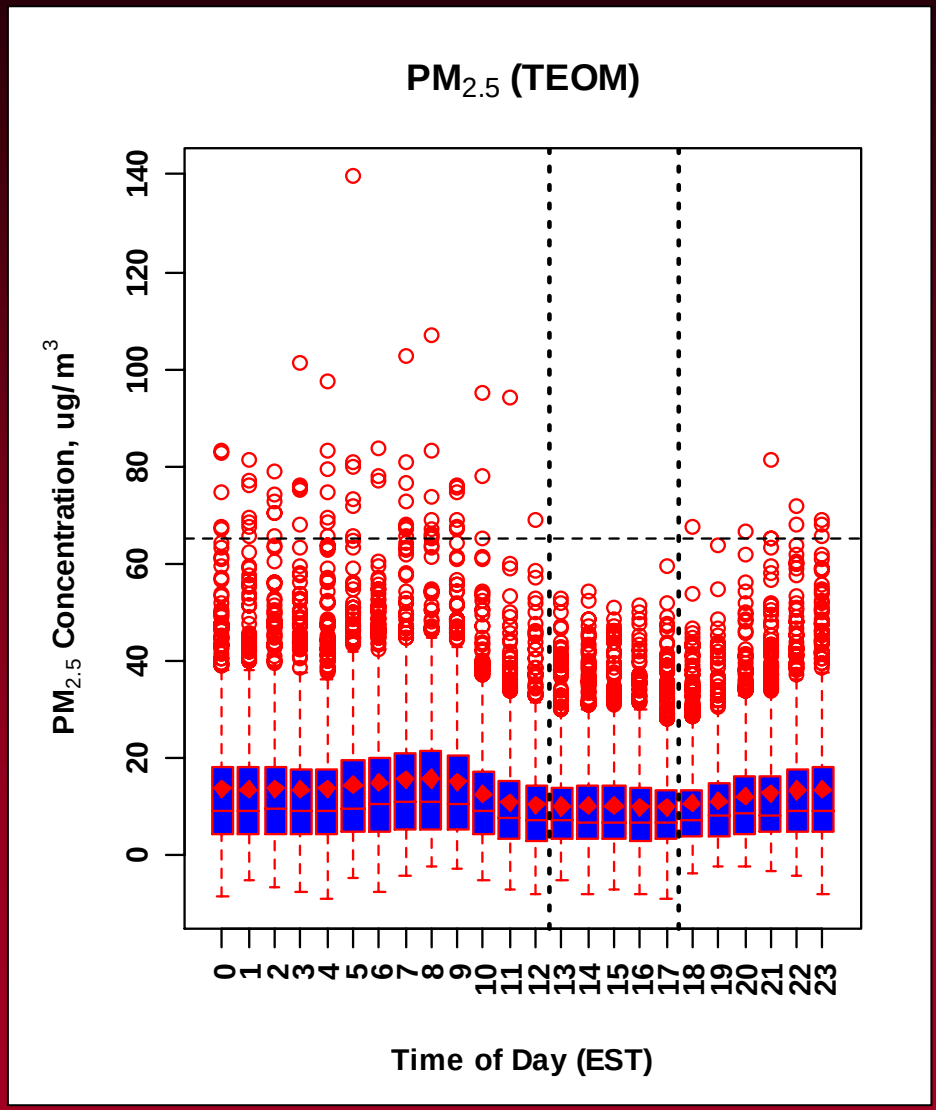


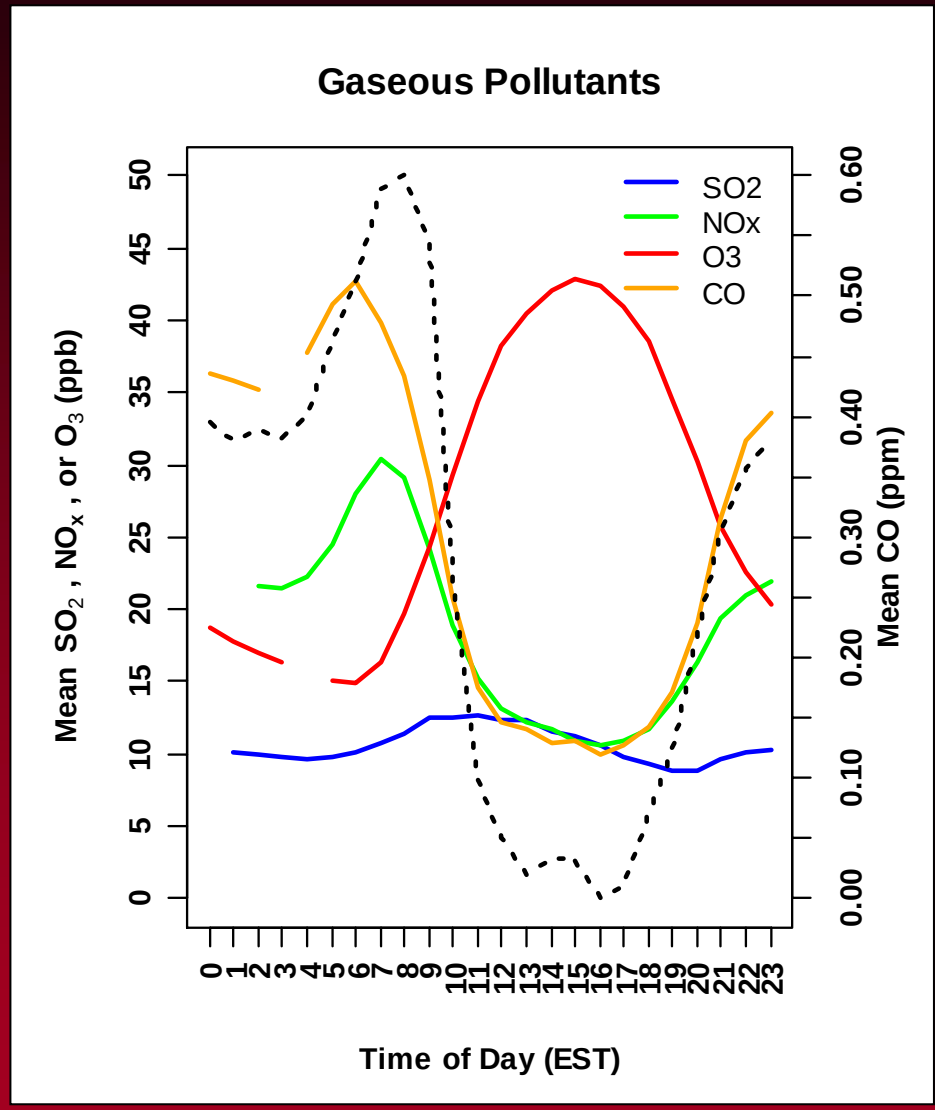
$R^2 = 0.03$
$m = 0.16$



$R^2 = 0.52$
$m = 0.53$

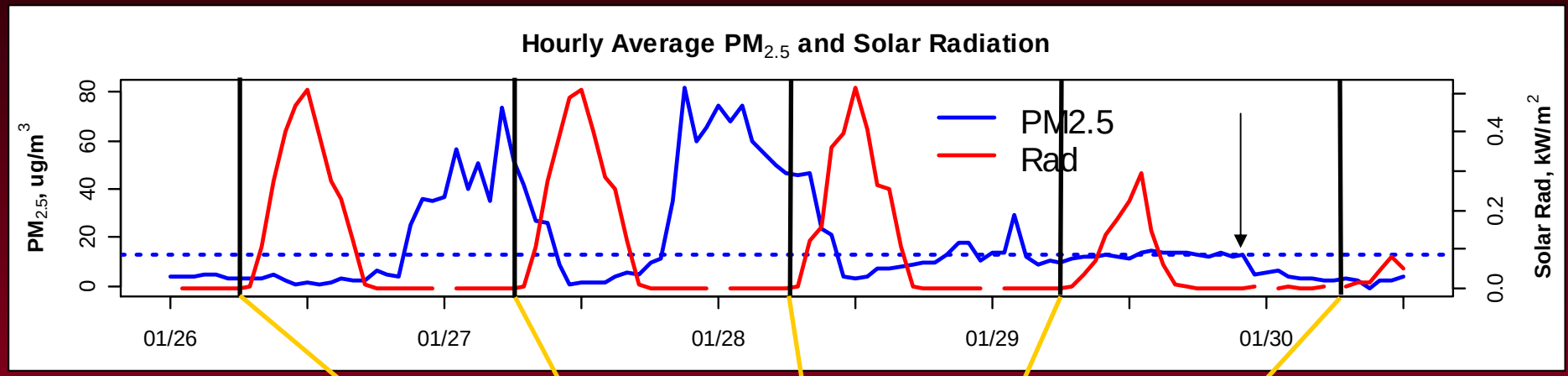
Diurnal Variability

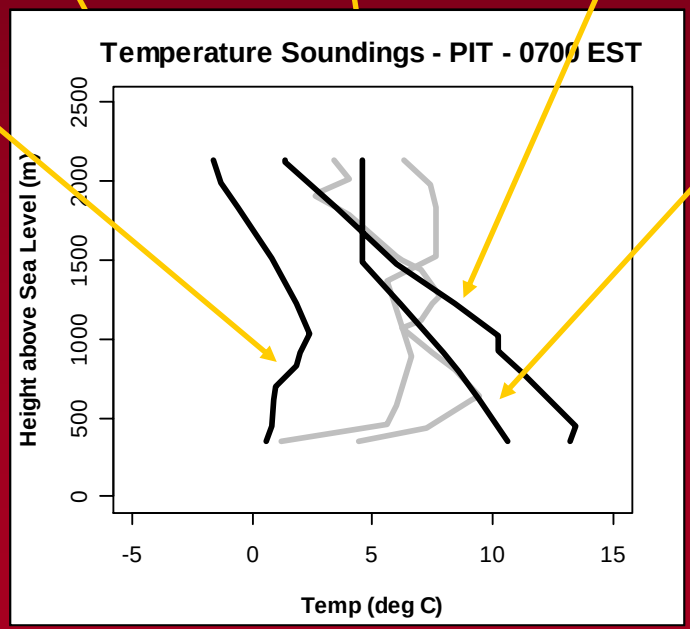




$PM_{2.5}$ Episode – Hourly Data

January 26 – January 30, 2002





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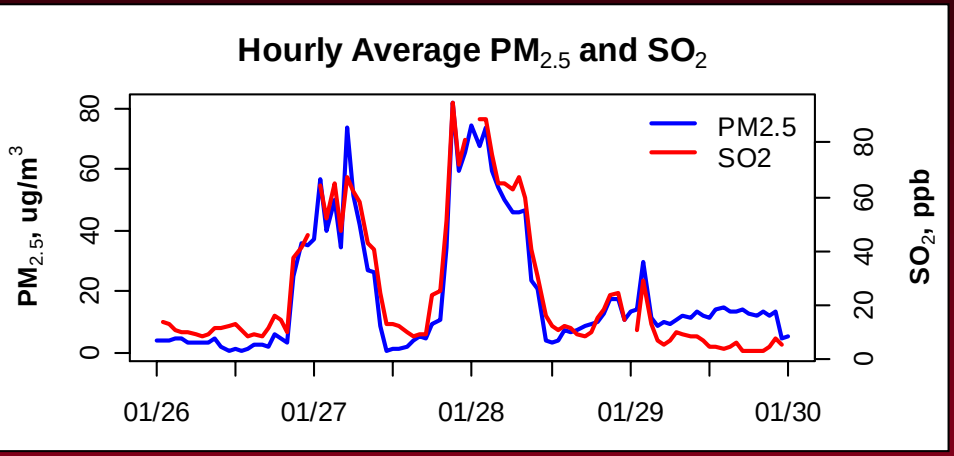
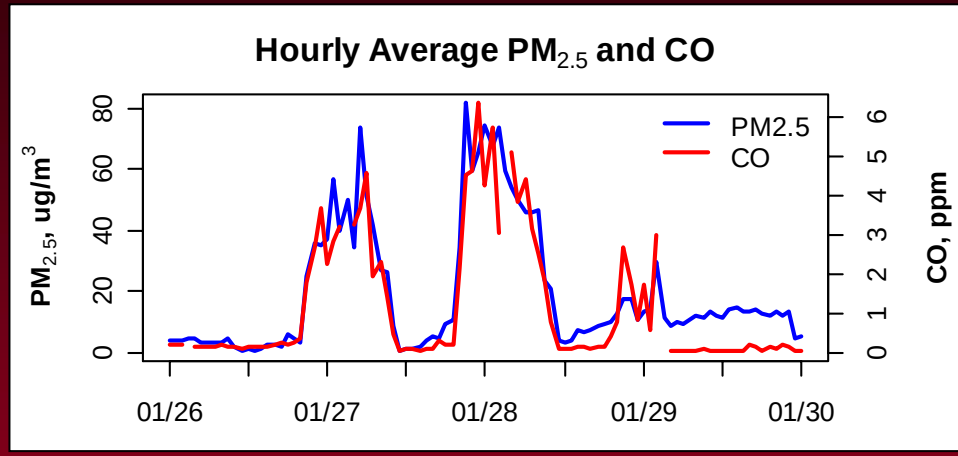
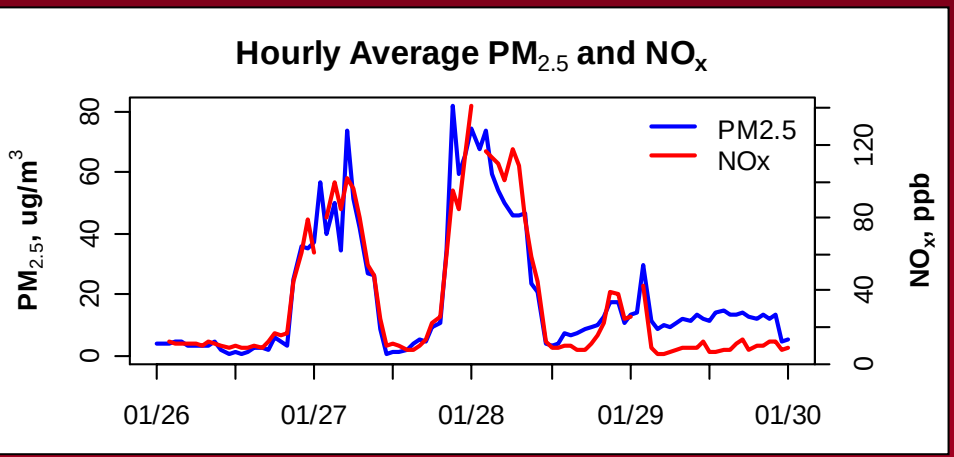
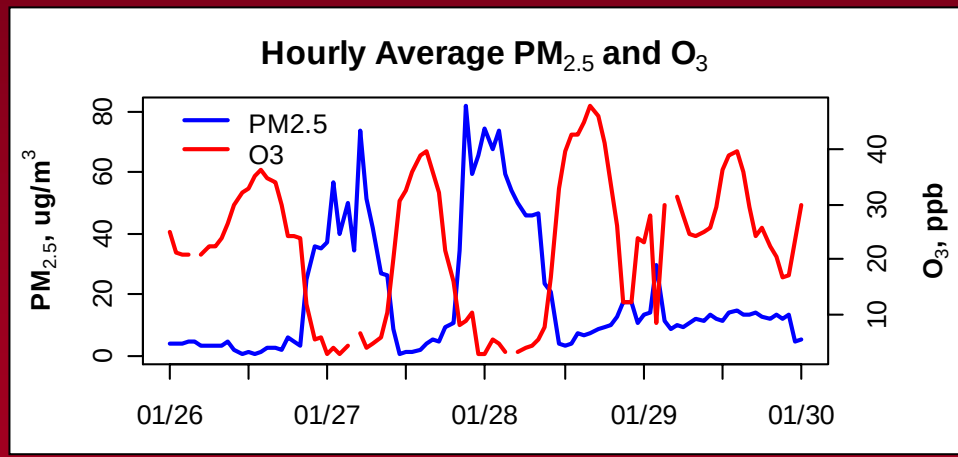


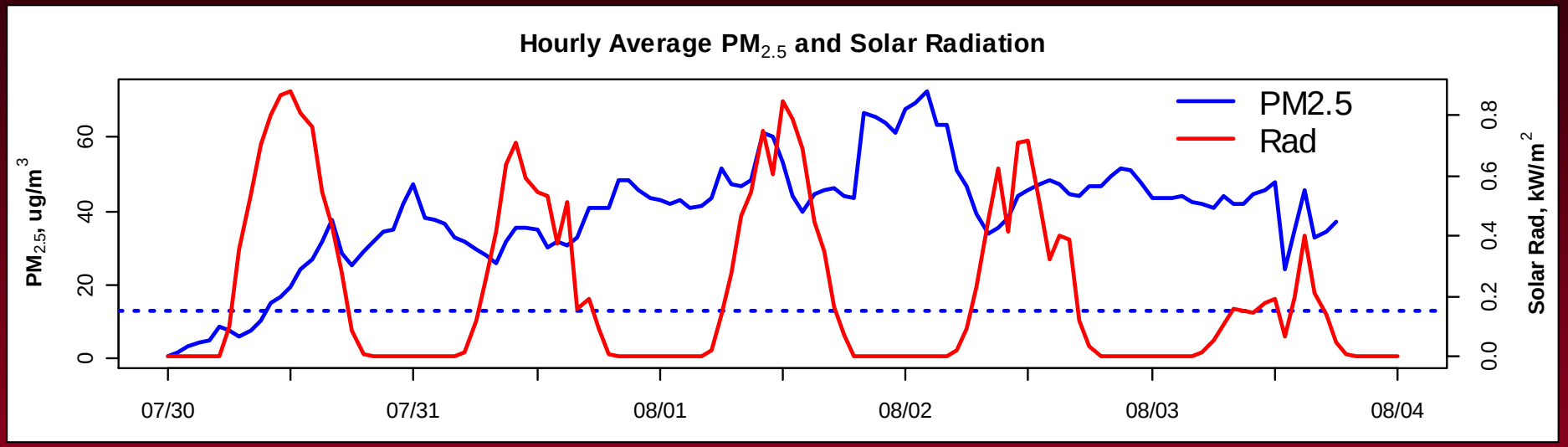


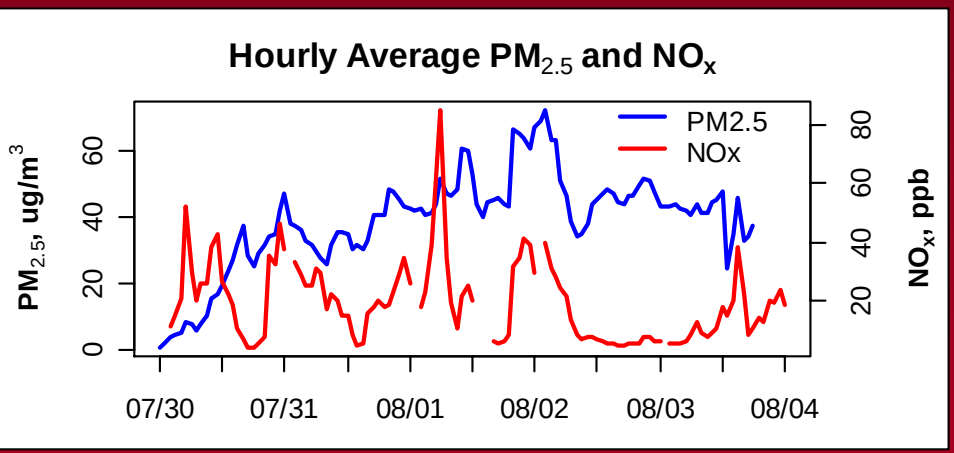


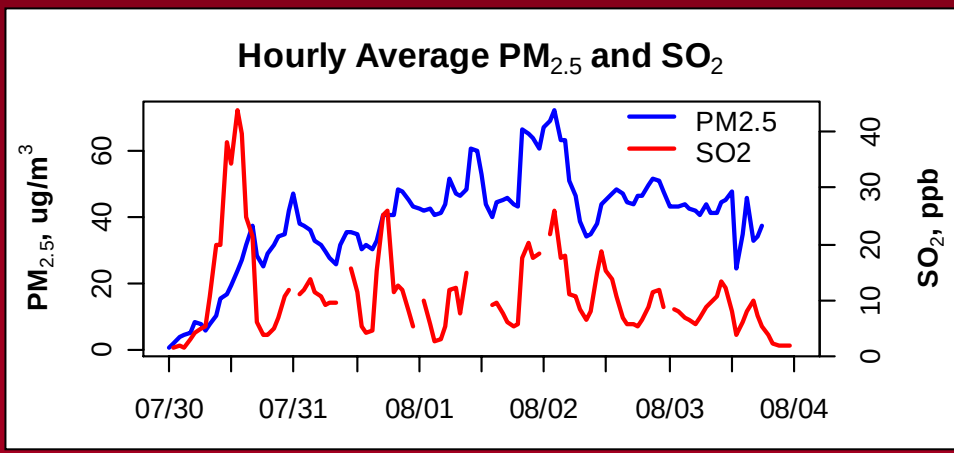


$PM_{2.5}$ Episode – Hourly Data

July 30 – August 4, 2001

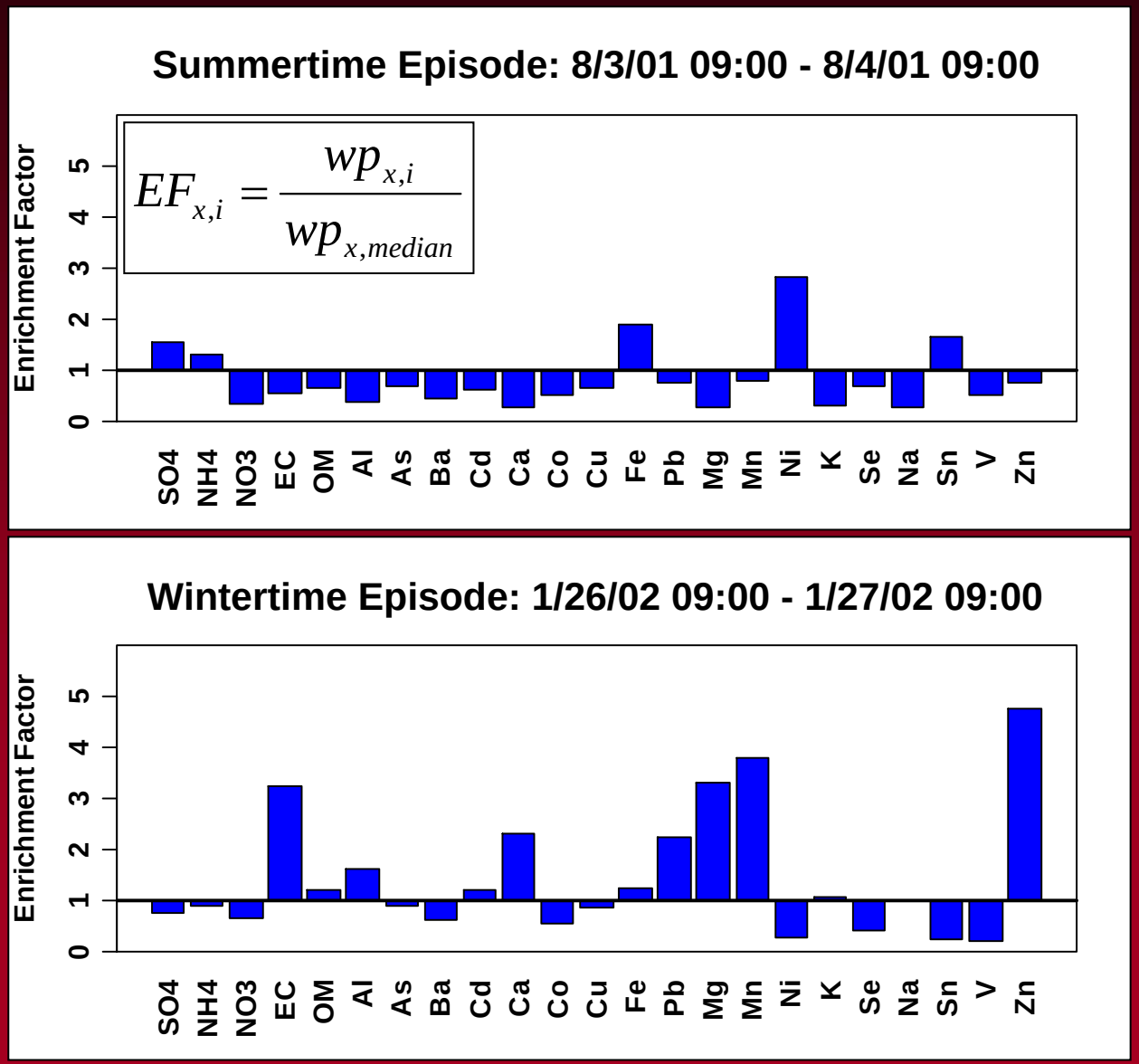






$PM_{2.5}$ Composition During Episodes

Ions, Carbon, Elements in Water-Soluble Fraction



Summary

- Average $PM_{2.5}$ concentration in Steubenville has decreased by more than 10 μg/m^3 since Six Cities Study; still more than 3 μg/m^3 above annual NAAQS (based on 2000-2002 data)
- Sulfate (31.3 wt%) and organic material (25.0 wt%) are the major components of $PM_{2.5}$ in Steubenville
- Local sources on average contribute an estimated 4.6 μg/m^3 to Steubenville's $PM_{2.5}$ concentration
  - Sulfate, Nitrate, and Ammonium account for about 2 μg/m^3
  - Among elements within the water-soluble fraction, Mg, Mn, Zn, and Fe show the greatest percent urban increment
- $PM_{2.5}$ concentrations were positively associated with CO, NO_x, and SO_2 concentrations
  - Associations between $PM_{2.5}$ and some gaseous pollutants (i.e., NO_x and CO) were strongly dependent upon season

Summary

- $PM_{2.5}$ exhibited a diurnal pattern similar to CO and NO_x; concentrations > 65 µg/m^3 were never observed during the mid-afternoon
- High $PM_{2.5}$ concentrations tended to occur on warm, high-pressure days; low concentrations tended to occur on cool, windy days with low solar radiation
- $PM_{2.5}$ episode case studies:
  - Cool season (nocturnal temperature inversions)
    - $PM_{2.5}$ concentrations showed strong diurnal variation
    - Strong associations among $PM_{2.5}$, NO_x, CO, SO_2
    - Enrichment: Zn, Mn, Mg, EC, Ca, Pb
  - Warm season
    - $PM_{2.5}$ concentrations more chronically elevated
    - Associations among $PM_{2.5}$ and gases not as strong
    - Enrichment: SO_4^{2-}, NH_4^+, Ni, Fe, Sn

Publications

- Connell et al. (2004) The Steubenville Comprehensive Air Monitoring Program (SCAMP): Overview and Statistical Considerations, *J. Air & Waste Manage. Assoc.*, in press.

- Connell et al. (2004) The Steubenville Comprehensive Air Monitoring Program (SCAMP): Associations Among $PM_{2.5}$, Co-Pollutants, and Meteorological Conditions, *J. Air & Waste Manage. Assoc.*, in press.

- Connell et al. (2004) The Steubenville Comprehensive Air Monitoring Program (SCAMP): Analysis of Short-Term and Episodic Variations in $PM_{2.5}$ Concentrations Using Hourly Air Monitoring Data, *J. Air & Waste Manage. Assoc.*, in press.

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